FDM 13-1-1 Drainage Practice Background

December 18, 2015

1.1 Introduction

The Director of the Bureau of Project Development (BPD) is the originator of this chapter.

1.2 General

Drainage has long been recognized as one of the primary considerations of highway construction. Its importance can be noted from the cost involved in providing drainage facilities for the highway, and for this reason alone a careful and scientific approach to drainage design should be taken. The purpose of this chapter is to provide a guide to existing standard procedures for drainage design throughout the state. The goal of design is to plan optimum drainage facilities considering function versus cost while meeting environmental requirments.

The methods of hydrologic and hydraulic analysis provided in this chapter will give the designer information necessary for drainage analysis. Experience and sound engineering judgment are not to be ignored and may at times differ from results obtained using methods in this chapter. Careful weighing of experience, judgment, and procedure are necessary for optimal drainage design. Terminology that is unique to this chapter and to "drainage" in general is defined in Attachment 1.1.

1.3 Basic Statewide Practice

In designing highway drainage systems, the three major considerations are:

1. The safety of the traveling public;
2. The use of sound engineering practices to economically protect and drain the highway;
3. In accordance with reasonable interpretation of the law, the protection of private property from flooding, water-soaking, or other damage.

In general, the hydraulic adequacy of pipe culverts shall be determined by the region based on sound hydrologic and hydraulic techniques and performance records at the same or similar locations. No improvement in the drainage of areas outside the right-of-way should be considered unless the state would benefit thereby or the project is financed by others.

1.4 Design Responsibility

The Bureau of Structures (BOS) is responsible for the hydraulic and structural adequacy of all cast-in-place and precast box culverts and bridges. Preliminary hydrologic and hydraulic computations for such structures shall be performed by BOS or consultant staff. A hydraulic/sizing report shall be prepared by BOS or consultant designers (refer to FDM 13-1-10, and Chapter 8 (hydraulics) of the LRFD Bridge Manual).

In addition, a Structure Survey Report is required for all hydraulic structures designed or reviewed by BOS. Refer to Chapter 6 of the department's LRFD Bridge Manual for report procedures. The region is responsible for the hydraulic adequacy of all other types of drainage structures.

BOS should be notified whenever it is proposed to replace an existing bridge with a pipe culvert(s) so that records of existing bridges may be kept current. Refer to the bridge manual for bridge definition:

http://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/strct/bridge-manual.aspx

The Statewide Drainage Engineer in the Bureau of Project Development shall be notified when plans include the box-shaped storm sewer. The Statewide Drainage Engineer will consult with the Bureau of Structures to determine the design requirements for the storm sewer and whether a structure number will be assigned.

1.5 Common Drainage Law

Drainage Common law is that body of principles found in court decisions based on customs, practices, and precedents that have evolved and are unwritten in statute or code.

According to Harold H. Ellis (1), Wisconsin's common law rules relating to diffused surface waters are as follows:

1. A lower owner may legally treat diffused surface waters as his enemy and prevent them from coming

onto his land.

2. The upper owner has a right to alter the natural flow of diffused surface waters and may discharge them upon lower land, subject to the following limitations:
   - The water must be expelled onto the lower land without malice.
   - The actions of the upper owner may extend no further than reasonably necessary to protect himself or his land.
   - Such water may not be diverted into another watershed.
   - The upper owner may not unduly collect such waters in a pond or reservoir and thereafter discharge them on his neighbor's land or on his own land in such close proximity to his neighbor that they will inevitably permeate and percolate so as to permanently injure the neighbor's soil.

Because the upper owner must not be negligent and he must be reasonable in his use and improvement of his land, Wisconsin has moved to a middle ground, lying somewhere between the "common enemy rule (2)" and the "reasonable use rule (2)".

1.6 Statutory Drainage Law

When the Department of Transportation constructs a highway, the natural or pre-existing flow of surface water might be changed, and the effects of these changes might extend beyond the highway right-of-way to private property. The laws governing these matters are found in Chapter 88 of the Wisconsin Statutes, Drainage of Lands.

Section 88.87 of this chapter states that a highway "*...shall not impede the general flow of surface water or stream water in any unreasonable manner so as to cause either an unnecessary accumulation of waters flooding or water-soaking uplands or an unreasonable accumulation and discharge of surface waters flooding or water soaking lowlands.*" It further states that these highways "*...shall be constructed with adequate ditches, culverts, and other facilities as may be feasible, consonant with sound engineering practices, to the end of maintaining as far as practicable the original flow lines of drainage.*" The section also provides that drainage rights or easements may be purchased or condemned to aid in the prevention of damage to property owners, which might otherwise occur as a result of the highway construction. (WisDOT does not intend to acquire easements as a routine solution to drainage problems (refer to FDM 13-1-5, Drainage Rights and Easements).

It is the duty of every landowner to provide, and at all times to maintain, a sufficient drainage system to protect the highway from water damage or flooding, by directing the flow of surface waters into existing highway drainage systems or by permitting the flow of such water away from the highway. Chapter 86, Section 86.07 (2) states that *"no person shall make any excavation or fill or install any culvert or make any other alteration in any highway or in any manner disturb any highway or bridge without a permit therefore from the highway authority maintaining the highway."*

In addition to Chapter 88, Section 86.075 covers the responsibility of a highway authority to notify the local drainage board *"Whenever a highway crossing any draining ditch of a drainage district governed by Chapter 88 is being constructed or reconstructed or a culvert in any such ditch is being replaced, the highway authority in charge of such work shall consult with the drainage board having jurisdiction of such district for the purpose of determining the depth at which such drainage ditch was laid out."* If any culvert or similar opening in a highway is installed at a grade higher than the depth at which a drainage ditch was laid out, the expenses involved in any future lowering of the culvert pursuant to Section 88.68 (4) shall be borne by the unit of government in charge of maintenance of the highway.

The Wisconsin State Statutes, Chapter 146, Miscellaneous Health Provisions also state, in Section 146.13; *"Discharging noxious matter into highway and surface waters (1) If anyone constructs or permits any drain, pipe, sewer or other outlet to discharge into a public highway infectious or noxious matter, the board of health of the village, town or city shall, and the town sanitary district commission or the county board of health, acting alone or jointly with the local board of health may, order the person maintaining it to remove it within 10 days..."* This Section further states (2)*" No person shall discharge by any means whatsoever untreated domestic sewage into any surface water as defined by s. 144.01(5), or drainage ditch governed by ch. 88; nor shall any person discharge effluents or pumpage by any means whatsoever from any septic tank, dry well or cesspool into any surface water as defined by s. 144.01(5), or drainage ditch governed by ch. 88 ..."*

The Wisconsin State Statutes, Chapter 236, Platting Lands and Recording and Vacating Plats, state, in Section 236.13, that *"approval of the preliminary or final plat shall be conditioned upon compliance with: ...(e) The rules of the Department of Transportation relating to provisions for the preservation of the public interest and investment in such highways."* This department rule is TRANS 233 that states as one of its basic principles: one of its basic principles in 233.02 (5) *"A land division map shall include provisions for the handling of surface drainage in such a manner as specified in s TRANS 233.105 (3)."* Section 233.105 (3) states (3) Drainage - The owner of land that directly or indirectly discharges storm water upon a state trunk highway or connecting highway shall submit to the department a drainage analysis and drainage plan that assures to a reasonable degree, appropriate to the circumstances, that the anticipated discharge of storm water upon a state trunk highway or connecting highway following the development of the land is less than or equal to the discharge preceding the development and that the anticipated discharge will not endanger or harm the traveling public, downstream properties or transportation facilities. Various methods of hydrologic and hydraulic analysis consistent with sound engineering judgment and experience and suitably tailored to the extent of the possible drainage problem are acceptable. Land dividers are not required by this subsection to accept legal responsibility for unforeseen acts of nature or forces beyond their control. Nothing in this subsection relieves owners or users of land from their obligations under S.88.87 (3)(b), stats.

Note: In section 88.87 (1), Stats., the Legislature has recognized that development of private land adjacent to highways frequently changes the direction and volume of flow of surface waters. The Legislature found that it is necessary to control and regulate the construction and drainage of all highways in order to protect property owners from damage to lands caused by unreasonable diversion or retention of surface waters caused by a highway and to impose correlative duties upon owners and users of land for the purpose of protecting highways from flooding or water damage. Wisconsin law, section 88.87 (3), Stats., imposes duties on every owner or user of land to provide and maintain a sufficient drainage system to protect downstream and upstream highways. Wisconsin law, section 88.87 (3)(b), Stats., provides that whoever fails or neglects to comply with this duty is liable for all damages to the highway caused by such failure or neglect. The authority in charge of maintenance of the highway may bring an action to recover such damages, but must commence the action within 90 days after the alleged damage occurred. Section 893.59, Stats.

The plats should be reviewed to ensure they conform to this principle.

For further details on drainage law, the designer is referred to:

- Wisconsin State Statutes, “Miscellaneous Highway Provisions,” Chapter 86.
- Wisconsin State Statutes, “Floodplain Zoning,” Chapter 87.
- Wisconsin State Statutes, “Drainage of Lands,” Chapter 88.
- Wisconsin State Statutes, "Water, Sewage, Refuse, Mining and Air Pollution," Chapter 144.
- Wisconsin State Statutes, "Miscellaneous Health Provisions,” Chapter 146.
- Wisconsin State Statutes, “Platting Lands and Recording and Vacating Plats,” Chapter 236.
- Wisconsin Administrative Code, Chapter TRANS 233.

REFERENCES

(1) Ellis, Harold H.; Beuscher, J.H.; Howard, Cletus D.; De Braad, J. Peter; "Water-Use Law and Administration in Wisconsin," Department of Law, University Extension, The University of Wisconsin, First Edition, 1970, 694 pp.

(2) "Guidelines for the Legal Aspects of Highway Drainage," Volume V-Highway Drainage Guidelines, AASHTO, 2007, 24 pp.

LIST OF ATTACHMENTS

Attachment 1.1 Glossary of Terms

FDM 13-1-5 Major Drainage Guidelines and Criteria — *December 18, 2015*

5.1 Definition

This procedure defines the major drainage issues and sets guidelines and criteria for more detailed studies, when appropriate. More detailed studies, when required, are completed in the design phase of project development. Three basic questions are asked:

1. Are major drainage problems anticipated?
2. Are the available general drainage guidelines appropriate for solving the anticipated problems?
3. What are the surface drainage alternatives?

These questions should be asked and resolved at the region. The Bureau of Project Development function is to update and clarify the major drainage guidelines, as necessary.

5.2 General Guidelines

To clarify the study of major drainage, it is helpful to consider some typical guidelines. For the most part, these are statutory "guidelines" or traditional practices set up by the Department of Transportation. They are broad practices, the changing of which would have an immediate, statewide effect on adjacent properties. Therefore, they are not subject to random change by either the region or the central office.

The general guidelines are:

1. Water Accumulation: The highway shall not impede the general flow of surface water or stream water in any unreasonable manner so as to cause either an unnecessary accumulation of waters flooding or water-soaking uplands, or an unreasonable accumulation and discharge of surface waters flooding or water-soaking lowlands (from Section 88.87, Wisconsin Statutes). This objective should be accomplished by:
   - Anticipating the amount and frequency of storm runoff.
   - Determining natural points of concentration and discharge and other hydraulic controls.
   - Determining the necessity for protection from floating trash and debris.
   - Comparing and coordinating proposed design with existing drainage structures and systems handling the same flows.
   - Removing detrimental amounts of surface and subsurface water.
   - Providing the most efficient disposal system consistent with economy, the importance of the road, maintenance, and legal obligations.
   - Culverts designed with the intent to permanently impound water may be regulated by WDNR as dams. In general, this situation should be avoided because of the potential regulatory issues and the potential barrier to aquatic organism passage. The Statewide Drainage Engineer in Bureau of Project Development should be notified of any culvert designed to permanently impound water.
2. Drainage Districts: Any work that involves drainage districts must be coordinated with the drainage board of such district. The legal procedures for these cases are set forth in Chapter 86 of the Wisconsin Statutes (refer to FDM 5-15-1).
3. WisDOT and Wisconsin Department of Natural Resources (WDNR) Cooperative Agreement: The Department of Transportation shall design and construct drainage facilities in accordance with the spirit and intent of the WisDOT and WDNR Cooperative Agreement, a copy of which can be found in FDM 20-30-1.
4. 401 and 404 Permits: The necessity of 401 and 404 permits for a drainage facility should be determined by FDM 21-30-1.
5. Local Sewerage Commissions: Coordinate work with local sewerage commissions that are affected by the project.
6. Aquatic Organism Passage: The crossing of some streams by highways requires the construction of drainage facilities that will accommodate aquatic organism passage. In addition, other streams may require the construction of barriers at drainage structures in order to prevent the migration of rough fish or other invasive species. In the early stages of design, the WDNR shall be consulted when streams are involved that might require special drainage facilities. Moreover, if aquatic organism passage facilities are required at a drainage structure, a field review regarding questions on aquatic organism passage should be held with the WDNR. For culvert design including aquatic organism passage, the designer should consult with the Statewide Drainage Engineer responsible for AOP coordination.
7. Drainage Patterns: Highway reconstruction projects should match natural drainage patterns as closely as possible. New culverts should be located and designed to minimize change or disruption in the natural flow of water, commensurate with cost.

   When the highway is in fill, the amount of special ditching along the fill slope should be minimized except where required to protect the adjacent land.

   When a highway is constructed on relocation, changes in surface drainage are more significant. Culverts should be placed at natural draws or depressions. Culverts should be placed frequently enough to avoid excessive concentration of flow.
8. Headwater: Criteria for culvert headwater is generally set as 1.5 times the pipe diameter, or no overtopping of roadway for design storm event, provided there is no risk of damage to adjacent

upstream property. Headwater elevation shall have no rise in mapped zoned floodplains unless all requirements of the WisDOT/WDNR Cooperative Agreement are met.

9. Drainage Rights and Easements: Wisconsin Statutes provide WisDOT with the authority to acquire drainage rights and easements. However, WisDOT does not intend to acquire easements unless it is determined that significant damage would occur to private property or that the cost of a larger structure (designed to accommodate the regional flood) would not be justified.
10. Overflow Section: These sections are considered for special situations (refer to FDM 13-10-1).
11. Maintenance Considerations: For future maintenance considerations the designer should provide:
    - Sufficient erosion protection for channel banks, for the highway, and for culvert outlets to prevent scour or erosion on private land.
    - Large enough culverts for ease of maintenance.
    - Curbs or berms and downslope pipe or gutters along fills of erodible material.
    - Drainage easements wide enough for maintenance equipment.
    - Access at drainage facilities for power equipment.
    - Debris catches where needed.
    - Corrosion-resistant structures in areas with corrosive soils and waters.
    - Interceptor ditches along the top of cut slopes.
    - Necessary drainage structures should be located, if possible, beyond the clear zone (refer to FDM 11-15-1). Where this is not possible, suitable protective barriers should be provided.

5.3 Surface Data Collection

5.3.1 Probable Working Media for Major Drainage Studies

The designer will usually be working from an aerial mosaic with a scale of 1" = 200' to 1" = 800' (1:2400 to 1:9600). LiDAR elevation data and 2-foot contours are available for many counties through data-sharing agreements. Countywide digital orthophotos may be obtained through the USDA NAIP at:

www.wisconsinview.org

Soils data can be found in NRCS Soil Survey Maps and digitally from the NRCS Geospatial Data Gateway.

5.3.2 Input Data Requirements

Desirable data will be of a general nature, as follows:

1. Watershed characteristics
2. Stream crossing locations
3. Climate information
4. Limiting design factors
5. Information on existing structures that would be readily available from logs, etc.
6. General information from local sources as to history of flooding and obvious problem areas.
7. Land use/cover
8. Soils data

5.3.3 Output Data

Desirable output data requirements are as follows:

1. Design discharge.
2. Proposed facilities.
3. Drainage easements.
4. Cost.

FDM 13-1-10 Documentation of Hydrologic/Hydraulic Design December 18, 2015

10.1 Introduction

Documentation of all hydrologic data and hydraulic design computations shall be assembled for each project and retained in the project files at the Region office. This documentation should contain all pertinent information used to design the drainage facilities and should be extensive enough to verify at a later date the hydraulic design of any structure. It should also include any information about special commitments placed on the project for environmental or public involvement reasons.

Hydrology and hydraulic design documentation is to be stored in the Region Central file system for25 years (Refer to RDA 00145-000, Roadway Drainage Hydrologic & Hydraulic Studies and Design Calculation). The documentation must be provided to the project manager, who will send it to the Region Central file system.

Implementation Schedule: The Stormwater-Drainage-Water Quality (WQ) Report Spreadsheets along with the Channel and Chute Design Spreadsheet Worksheets are available for immediate use. Projects are required to use and submit the worksheets starting with the November, 2013 PS&E due date Project Letting Process.

10.2 Bridge and Box Culvert Design

The hydraulic design documentation for a bridge, box culvert or other large drainage conduit requiring structural analysis shall contain a segment entitled "Discussion of Structure Sizing." This discussion should concisely summarize the engineering judgments that determined the structure size (waterway opening). Relevant factors to be highlighted include: relative construction cost considerations, environmental concerns, compatibility with local floodplain zoning ordinances, and risk considerations such as minimization of flooding, potential damages to abutting property, and protection of the motorist and/or highway.

A stream crossing structure survey report (SSR) should be prepared by the Region and forwarded to the Bureau of Structures (BOS) if the structure is to be designed by BOS. If the structure is to be designed by a consultant, the SSR should be submitted to BOS for review along with the preliminary structure plans and the hydraulic/sizing. Referred to in the preceding paragraph. See Chapter 8, Appendix A, of the WisDOT LRFD Bridge Manual for a sample hydraulic report (referred to as a "Sample Bridge Site Report").

BOS will perform the hydraulic/hydrologic analysis for all bridges and box culverts that are designed by the Department. Consultants are responsible for the hydraulic/hydrologic analysis of the bridges and box culverts they design.

10.3 Stormwater Report Applicability

Each WisDOT project that has a stormwater component must have a completed Stormwater-Drainage-Water Quality (WQ) Report spreadsheet. A Stormwater-Drainage-WQ Report is not needed for projects that have no change to the culvert or storm sewer system that drains the project or for projects that do not trigger TRANS401 water quality requirements. Typically, traffic control, ITS (Intelligent Transportation Systems), signalization, or safety projects will not need a stormwater report. Overlay projects that do not include culvert replacements, extensions, or other modifications are also exempt from the stormwater reporting requirement.

The Drainage Summary Worksheet should be submitted at the 30% design stage to describe any significant flow changes and what may need to be done to address the changes in flow. The intent of this early submittal is to note potential drainage problems at an early stage. The updated Summary Worksheet and the initial Data Worksheet should be submitted at the 60% design stage. This submittal should address the concerns brought up in the previous Drainage Summary Worksheet, any new issues, and include available information in the Data Worksheet. This submittal should also include any available drainage calculations or model analyses and drainage mapping. The final design submittal includes the completed Drainage Summary and Data Worksheets as well as all supporting documentation needed to review the worksheets.

The stormwater report spreadsheet is not applicable to bridges and box culverts designed or reviewed by Bureau of Structures nor is it applicable to storm sewer design.

10.4 Design Documentation

Each WisDOT project that has a stormwater component must develop a design for those components that includes the basin hydrology and the structure or system hydraulic design. The type and extent of the documentation for these components will vary, but the basic information includes the hydrology and hydraulic design information listed below. A summary of this information should be included in the Drainage-Stormwater Report spreadsheet described below. This spreadsheet provides a way for a designer to methodically describe the objectives and design of a project drainage system.

<u>Hydrology</u>

1. Design frequencies.
2. Methods used to compute the flow rates and the limitations of these methods.
3. The type and extent of future development and how it was considered in the design process.
4. List of all graphs that were used to determine rainfall depth, rainfall intensity, runoff, and time of concentration.
5. Any information that is used by the designer as general criteria for the determination of flow rates for ditches and culverts.
6. Location map indicating each drainage area. Show the drainage areas in the form of a mosaic on a 1 inch = 100-foot, (1:1200) scale, photogrammetric, contour map. Large drainage areas should be shown on USGS contour maps.
7. A statement of the characteristics of the drainage pattern with regard to soil types, land usage and relief, special controls on the flow rates, possible future development effects, past flood of record, and any information that is needed to properly analyze the flow rate for the given drainage area and detailed computations of the flow rate.

Hydraulic Design

1. Detailed hydraulic design for each culvert location and each channel and ditch on the project.
2. A statement on any information gathered during the field review of the drainage area.
3. For culverts, provide the design work sheet or the computer design sheet for the culvert, which should contain information on the discharge, allowable headwater elevation, design headwater elevation, design tail-water depth, entrance conditions, grade of flow line, discharge velocity, freeboard (allowable headwater-roadway elevation), etc. This sheet should show designs for various types of inlet conditions and culvert materials, along with the final recommendation of the culvert used in the final design.
4. For storm sewer systems, include the urbanization factors, cost analysis, and any other factors that may affect the final design of the storm sewer. Provide a layout of the storm sewer system along with the contributing drainage areas, and a detailed design tabulation sheet showing the grate inlets, flow rates contributing to each inlet, and pipe sizes.

This documentation, initiated during the preliminary design stage, must be updated to reflect the final design. The stage of the design can be noted in the Drainage-Stormwater Report submittal described below on the Drainage-Summary worksheet.

As part of design documentation, the designer should determine whether a project is located within a regulatory floodplain. Unofficial floodplain maps can be viewed on WDNR's Surface Water Data Viewer:

http://dnr.wi.gov/topic/surfacewater/swdv/

Official Flood Insurance Rate Maps can be viewed and printed in "FIRMette" form at FEMA's Map Service Center under the Product Catalog at:

https://msc.fema.gov/

10.5 Stormwater-Drainage-WQ Report Spreadsheet Instructions for Drainage Design

There are two components to the spreadsheet: drainage and water quality. This section describes how to fill out the stormwater drainage worksheets of the report. Refer to FDM 10-30-1 for instructions on how to fill out the water quality worksheet sections of the Report.

The stormwater drainage section of the spreadsheet has two parts. The first part, which is on the 'Drainage-Summary' worksheet tab, is the Summary worksheet. This worksheet includes basic project information, (project name, limits, county, etc.) and a list of questions that will help the designer determine the drainage requirements for the project.

The second part of the stormwater drainage is a table of the stormwater flow and drainage issues that typically occur in a project. This list is in the 'Drainage-Data' worksheet tab and includes the following topic areas:

1. Outfall Information
2. Basic Subbasin Drainage Information
3. Urban/ and/or TRANS 401 Project Information (see FDM Chapter 10 for TRANS 401 requirements)

4. Culvert Design
    a. Existing Culvert Data
    b. Proposed Culvert Design
    c. Floodplain Management
    d. Drainage District Issues
    e. Aquatic Organism Passage
5. Culvert Liner Design
    a. Existing Culvert Data
    b. Liner Details
    c. Floodplain Management
    d. Drainage District Issues
    e. Aquatic Organism Passage

The spreadsheet includes an outline feature that allows the user to collapse topic groups that are not relevant for the project to make the worksheet easier to use.

There are ten worksheets in the Stormwater-Drainage-WQ Report spreadsheet. The Stormwater Water Quality Summary worksheet and the water quality control practice worksheets, which all begin with the letters 'WQ', are discussed in FDM 10-30-1. The Drainage-Summary worksheet and the Drainage-Data worksheet are described below.

10.5.1 Drainage Summary Worksheet

This worksheet includes basic project information and a Drainage Summary page that includes questions that address drainage issues (refer to Attachment 10.1 and 10.2). Water quality questions and issues are addressed in FDM 10-30-1. Be sure to enable the spreadsheet Macros by clicking on the security warning "options" box on the top of the spreadsheet and then highlight the "enable this content" button.

10.5.1.1 Basic Project Information

Basic project information includes information like the project number and name. When entering this information, only enter it in columns B and C of this worksheet; the appropriate information will be copied to other worksheets by the spreadsheet.

Please note that the planning stage generally includes only the water quality component of stormwater management unless drainage considerations are part of a planning study.

10.5.1.2 Drainage - Summary Narrative

The drainage summary narrative begins with line 15 on the "Drainage-Summary" tab of the stormwater report spreadsheets. This narrative is a series of questions that will, when completed, define the drainage goals, objectives, and issues for the project and how they were met. Enter your response in the cell below each question.

Line 15: IS THERE A SIGNIFICANT FLOW INCREASE OR DECREASE WITHIN ANY SUB BASIN? IF YES, DESCRIBE THE REASON.

This question is intended to describe why any significant (greater than 5%) flow increases or decreases occur in the project. Examples of an explanation and justification could include "Outfall 3: New connection to municipal storm sewer system" or "Outfall 8: Outfall location shifted and combined with adjacent upstation drainage basin to avoid concentrated discharge to wetland.

Line 17: IS THERE A SIGNIFICANT IMPERVIOUS AREA CHANGE TO ANY SUB BASIN? IF YES, DESCRIBE THE REASON.

Increases in impervious surface area are often the result of added lanes, new alignment, or park and ride lots, etc. However, the impact on peak rate discharge may be insignificant if the impervious area is a small portion of the subbasin or if the impervious area is located near the outfall. Increased impervious surface will increase the runoff volume. The impact of the increased impervious area may be significant if the overall drainage basin is small or if the added discharge from the impervious area reaches the outfall at the same time as the peak flow from the balance of the drainage bas

Line 19: HAVE THE DRAINAGE SUB BASIN AREAS OR FLOW PATHS CHANGED SIGNIFICANTLY? IF YES, DESCRIBE THE REASON.

Altered flow paths may change the size of the drainage basin and affect the downstream drainage system. Existing ponds and wetlands may be affected if tributary drainage is relocated. Peak discharge rate increase may increase the potential for streambed erosion. Document the reason for the drainage area re-routing, and describe erosion control plans to address increased peak discharge rates.

Line 21: DESCRIBE THE PROPOSED DRAINAGE CONVEYANCE AND CONTROL SYSTEMS.

The conveyance system may include any combination of drainage swales, culverts and/or storm sewers. Control systems may include detention ponds, diversion structures, etc.

Line 23: DESCRIBE ANY AQUATIC ORGANISM PASSAGE ISSUES.

If one or more culverts in the project require aquatic organism passage design, describe the water body classification, the requesting agency, and reason for request. Complete the AOP section of the Stormwater Report Drainage-Data section for the culvert(s).

Line 25: DESCRIBE ANY EXCEPTIONS TO WisDOT FDM CHAPTER 13 DRAINAGE REQUIREMENTS,

Document and explain any exceptions to the FDM Chapter 13 drainage design requirements. Examples may include the use of 12-inch diameter storm sewer pipes or wide-bottom special ditches.

Line 27: DESCRIBE WDNR COORDINATION.

Provide name of WDNR liaison, date of correspondence, and attach printed copy of correspondence.

Line 29: DESCRIBE ACCOMMODATIONS TO MEET LOCAL, MUNICIPAL, OR REGIONAL DRAINAGE OR STORMWATER MANAGEMENT THAT EXCEED FDM CHAPTER 13 REQUIREMENTS.

Sometimes accommodations are made to meet drainage design standards that exceed WisDOT FDM Chapter 13 design requirements. For example, a community may want a detention pond to decrease peak flows in the off-DOT ROW drainage area, or may want all drainage structures in their jurisdiction to meet their higher design standards so the entire drainage system meets a consistent set of standards. If this occurs, document the accommodation, why it was made, and the source of funding for the modifications.

Line 31: DOCUMENT SIGNIFICANT IMPACTS TO THE PROJECT CAUSED BY DRAINAGE, PROJECT MANAGER CONCURRENCE IS REQUIRED. (PM SIGN AND DATE).

The project manager must acknowledge any significant drainage impacts or non-standard design changes to the project by signing this report or providing documented concurrence using, for example, an email message stating he or she has reviewed and approved of the report.

10.5.1.3 Drainage - Data Worksheet

The number of columns in the worksheet can increase as needed by highlighting the last unfilled column and dragging the small box in the lower right hand corner of the highlighted column to the right. The outfall numbers will increase consecutively.

As noted in FDM 13-1-10.4, there are a number of headings in the Drainage-Data spreadsheet. This section will review the contents of each heading.

If an explanation is required as part of the response to a line item in the report, provide the explanation on a separate attachment.

Section 1: Outfall Information:

Lines 8 – 28 should be completed for all outfalls, regardless of whether culverts or storm sewer system. Documentation for storm sewer systems should be attached to the Stormwater Report, but no information past Line 28 is necessary in the Stormwater Report.

Line 8: Outfall number.

Consecutively numbered outfalls from the start to the end of the project. An outfall is any culvert, roadside ditch, or storm sewer drainage discharge point with runoff either originating from or passing through the project right-of-way.

Line 9: Outfall discharges to:

Use the pull down menu to select the type of water body the outfall discharges to. The options are: 1) Overland, 2) Ditch, 3) Creek, 4) River, 5) Wetland, 6) Storm Sewer, 7) Combined Sewer, 8) Other.

Line 10: Waterway crossing type:

Use the pull down menu to select the type of waterway crossing. The options are: 1) Culvert, 2) Box Culvert, 3) Storm Sewer, 4) Three Sided Box Culvert, and 5) Bridge.

Line 11: If discharging to environmentally sensitive area, what kinds of buffers were used at outfall?

The options in the pull down menu are: 1) Swales, 2) Filter Strips, 3) Vegetated Embankment.

Line 12: Previous flooding issues or flow restrictions?

Select yes or no from the pull down menu. If yes, provide explanation.

Line 13: Is the drainageway in the DOT ROW a navigable waterway?

Select yes or no from the pull down menu.

Line 14: Classify the drainageway in the DOT ROW.

The options are: 1) Wetland, 2) 303(d) Waters, 3) Exceptional Waters, 4) Outstanding Waters, 5) Waters of the U.S.

Section 2: Basic Sub Basin Drainage Information:

Line 16: Outfall number.

Consecutively numbered outfalls from the start to the end of the project. An outfall is any culvert, roadside ditch, or storm sewer drainage discharge point with runoff either originating from or passing through the project right-of-way.

Line 17: Outfall station.

The station along the reference line where the outfall is located.

Line 18: Design storm frequency.

Enter the flood frequency used for the design of the culvert or storm sewer system. This value is typically found in FDM 13-10 Figure 1.1.

Line 19: Check storm frequency.

Enter the flood frequency used to check the design for unacceptable inundation of the highway facility or flooding. Refer to FDM 13-25-20 for additional information.

Line 20: Drainage area (ac).

Line 21: Hydrologic Method.

List the method used to compute the peak discharge rates for the design and check storms. Examples include, but are not limited to: the Rational Method, TR20/55, HEC-1/HMS, regional regression equations, and basin transfer methodology.

Line 22: Time of Concentration (min).

The time required from discharge to travel from the most hydrologically remote point in the drainage area to the outfall.

Line 23: C or CN.

Runoff coefficient, C, for use with the Rational Method can be found in FDM 13-10 Attachment 5.2, and Runoff Curve Numbers, CN, for use with TR20/55 can be found in FDM 13-10 Attachment 5.6.

Line 24: Rainfall Intensity (in/hr).

Rainfall intensity is used with the Rational Method for hydrologic computations, and can be found using the Intensity-Duration-Frequency (IDF) curves in FDM 13-10 Attachment 5.4.

Line 25: Rainfall Depth (in)

For hydrologic methods using a design storm to determine the peak discharge rate, record the rainfall depth of the design storm. SCS Type II distribution corresponds to National Weather Service Technical Paper 40 (1959) rainfall totals.

NOAA Atlas 14 rainfall data may be used with the WDNR and SEWRPC distributions, and require that a critical storm duration analysis be completed. MSE-3 and MSE-4 24-hour rainfall distributions replacing SCS Type II are available from NRCS for use with the NOAA Atlas 14 rainfall data at:

http://www.nrcs.usda.gov/wps/portal/nrcs/detail/wi/technical/engineering/?cid=nrcs142p2_025417

Line 28: Hydraulics design software used.

Record the design software used for drainage analysis and design.

Section 3: Urban/TRANS 401 Project Information:

This section, including lines 29-43 of the stormwater/drainage report form, is required only for urban projects or projects with TRANS 401 water quality requirements.

Line 31: DOT right of way area (acres).

Enter the area draining to the outfall that is within the WisDOT right-of-way.

Line 32: DOT right-of-way compared to sub-basin drainage area (%) (calculated).

This value is self-populated based on data in Lines 20 and 31. The relative drainage area information may be used when negotiating storm sewer cost share agreements between WisDOT and a municipality.

Line 33: DOT impervious area – existing (acres).

Enter the existing (pre-project) impervious surface area within the WisDOT right-of-way to outfall.

Line 34: DOT impervious area – proposed (acres).

Enter the proposed impervious surface area within the WisDOT right-of-way to outfall.

Line 35: Change in impervious area (calculated).

This value is self-populated based on data in Lines 33 and 34. This information may be used to determine possible reason for change in discharge and potential downstream impacts.

Line 36: Percent change DOT in impervious area (calculated).

This value is self-populated based on data in Lines 33 and 34. This information may be used to determine possible reason for change in discharge and potential downstream impacts.

Line 37: Proposed peak discharge rate (cfs), before detention

Design peak flow for the proposed drainage system, not including impacts of detention.

Line 38: Peak discharge rate change (cfs).

This value is self-populated based on data in Lines 26 and 37.

Line 39: Percent change peak discharge rate (%).

This value is self-populated based on data in Lines 26 and 37.

Line 40: Design peak discharge rate (cfs) post-detention:

Enter the design peak discharge rate for the proposed drainage system post-detention. If there is no detention, then this value is the same as the value in Line 37.

Line 41: Existing 2-year peak discharge flow (cfs):

The pre-project 2-year peak discharge rate for the drainage system.

Line 42: Proposed 2-year peak discharge flow (cfs)

The post-project, pre-detention 2-year peak discharge rate for the proposed drainage system.

Line 43: Proposed 2-year peak flow (cfs), (after detention,/in-line storage/other).

The design peak discharge rate for the proposed drainage system after any detention/ in line/other storage. If there is no detention, then this value is the same as the value in Line 42.

Section 4: Culvert Replacement/Extension Project Information

Culvert Design – Existing Culvert

Line 52: Manning's n:

Roughness values for common culvert materials can be found in Table B.1 of FHWA HDS-5.

Line 53: Inlet configuration:

Typical inlet configurations can be found in FHWA HDS-5, Chapter 1, Section 3.3. Choices in the drop down menu include: apron endwalls, mitered to slope, headwall, projecting.

Line 54: Upstream invert (ft)

Elevation of bottom of culvert at upstream end.

Line 55: Downstream invert (ft).

Elevation of bottom of culvert at downstream end.

Line 56: Length (ft).

Culvert length, not including apron endwalls or headwalls.

Line 57: Slope (%)

Value automatically calculated by dividing invert elevation difference by pipe length.

Line 58: Computed upstream water surface elevation (ft).

Upstream water surface elevation computed for design peak discharge using hydraulic computation program in steady state analysis mode or FHWA HDS-5 nomograph methodology.

Line 59: Tailwater elevation (ft).

Water surface elevation at pipe outlet, based on normal depth of downstream channel or average of critical depth and culvert diameter. See FHWA HDS-5 for more detail.

Line 60: Outlet velocity (ft/s)

Water velocity at outlet end of pipe.

Culvert Design – Proposed Culvert

Line 62 to 82: Proposed culvert information.

Lines 63-72 contain similar inventory of physical properties as lines 48-57 for the existing culvert.

Line 76: Change in upstream water surface elevation.

Value automatically computed comparing Line 77 and Line 58. Note that increases in upstream water surface elevation are generally discouraged, and may be prohibited without “appropriate legal arrangement” in mapped floodplains.

Line 77: Riprap outfall.

Size of riprap at culvert outfall, if necessary.

Line 78: Maximum allowable headwater (ft)

The maximum upstream water surface elevation.

Line 79: Maximum allowable headwater design criteria.

Drop down menu includes options of: existing conditions, shoulder subgrade point, or edge of pavement elevation, or headwater to culvert diameter ratio.

Line 80: Station of lowest subgrade shoulder point.

The sag point of the vertical curve over the proposed culvert.

Line 81: Elevation of lowest subgrade shoulder point (ft).

Top of subgrade at sag point of vertical curve.

Line 82: Headwater to pipe diameter ratio.

Value is automatically calculated based on depth at upstream end (highwater elevation minus invert elevation) divided by the culvert diameter or height.

Culvert Design - Floodplain Management

Line 84: Mapped floodplain.

To determine if the culvert is in a mapped floodplain, either check with the region stormwater engineer or view unofficial maps on the Wisconsin DNR Surface Water Data Viewer - FEMA Maps/DFIRMS at:

http://dnrmaps.wi.gov/sl/?Viewer=SWDV&layerTheme=1

Official Flood Insurance Rate Maps (FIRMs) can be found on FEMA's website at:

http://msc.fema.gov/portal

Line 85: Increase in headwater.

If there is an increase in water surface elevation, attach an explanation for the change and how the increased water surface profile was approved.

Culvert Design – Drainage District Issues

Line 87: Is culvert in a drainage district?

To determine if the culvert is in a drainage district, check with the region stormwater engineer or go to the web site:

https://datcpgis.wi.gov/maps/?viewer=dd

Line 89: Increase in headwater

If there is an increase in water surface elevation, attach an explanation for the change and how the increased water surface profile was approved.

Line 90: Drainage board approval?

Drainage board approval is required for increases in water surface profiles in areas located within incorporated drainage districts.

Culvert Design – Aquatic Organism Passage

Line 92: Is aquatic organism passage (AOP) a concern?

If AOP is considered in project, please include a copy of the WDNR Initial Review Letter.

Line 93: Does WDNR concur with the AOP design?

Provide documentation of WDNR concurrence.

Line 94: Embedment Depth

The depth of the inverts below the natural stream channel.

Line 95: Embedment Material

Description of the gradation of material in culvert. The material should match the native streambed material to the extent possible.

Section 5: Culvert Liner Design

Lines 99 – 133 should be completed for any project that includes a culvert liner.

Culvert Liner Design - Existing Culvert

Line 99: Outfall number.

Consecutively numbered outfalls from the start to the end of the project. This value is auto-populated.

Line 105: Manning's roughness

Use standard values for "n" (i.e. 0.013 for concrete, 0.024 for corrugated metal)

Line 106: Pipe geometry

Cross sectional shape of pipe (i.e. circular, elliptical, arch, etc.)

Line 107: Upstream invert

Elevation of the upstream end of the pipe.

Line 108: Downstream invert

Elevation of the downstream end of the pipe.

Line 109: Length (ft)

Length of pipe, not including endwalls or aprons

Line 110: Slope (%)

Automatically populated based on invert elevations and pipe length.

Line 111: Depth of cover over pipe (ft)

Minimum depth at between roadway surface and top of pipe

Line 112: Is overtopping an issue?

Based on observed erosion or reports of local residents, document any past observed overtopping.

Line 113: Upstream flooding risk?

Note and buildings or infrastructure that may be at risk if upstream water surface elevations are increased as a result of lining the culvert.

Culvert Liner Design - Floodplain Management

Line 125: Is the culvert in a mapped floodplain?

Select the pull down menu to answer either 'Yes' or 'No'. To determine if the culvert is in a mapped floodplain, either check with the region stormwater engineer or go to the Wisconsin DNR Surface Water Data Viewer – FEMA Maps/DFIRMS at:

http://dnrmaps.wi.gov/sl/?Viewer=SWDV&layerTheme=1

Official Flood Insurance Rate Maps (FIRMs) can be found on FEMA's website at:

http://msc.fema.gov/portal

Line 126: Will proposed liner increase water surface profile?

Select the pull down menu to answer either 'Yes' or 'No'. If the answer is yes, attach an explanation of the reason for the change and how the increased water surface profile was approved.

Culvert Liner Design – Drainage District Issues

Line 128: Is culvert in a drainage district?

Select the pull down menu to answer either 'Yes' or 'No'. To determine if the culvert is in a drainage district, either check with the region stormwater engineer or go to the web site:

https://datcpgis.wi.gov/maps/?viewer=dd

Line 129: Drainage District name.

Enter the name of the drainage district.

Line 130: Has the drainage board approved the use of a liner?

Select the pull down menu to answer either 'Yes' or 'No'. If the answer is no, attach an explanation of the reason why the drainage board did not approve the change.

Culvert Liner Design - Aquatic Organism Passage

Line 132: Is aquatic organism passage a concern?

Select the pull down menu to answer either 'Yes' or 'No'. If the answer is 'Yes', respond to the question on Line 135.

Line 143: Does WDNR agree with the AOP design?

Select the pull down menu to answer either 'Yes' or 'No'. If the answer is no, attach an explanation of the reason for why the WDNR did not approve the design.

10.5.2 Example Stormwater-Drainage-WQ Worksheet

A completed Stormwater - Drainage Worksheet example is provided within the downloadable zip Stormwater-Drainage files (refer to link at top of Attachment 10.1 and 10.2). It includes both an urban and a rural component. The first sheet is the drainage basin overview figure, which illustrates basins for the entire project. If the corridor is long, additional sheets may be appropriate. For this example, not all drainage areas and outfalls for the project are shown. The map sheets provide additional detail, at a closer scale, of the drainage system along the highway for selected basins. The map sheets are followed by a completed stormwater report that illustrates both grass swale and storm sewer drainage.

LIST OF ATTACHMENTS

Attachment 10.1	Stormwater-Drainage-WQ Report Spreadsheet: Drainage - Summary Worksheet
Attachment 10.2	Stormwater-Drainage-WQ Report Spreadsheet: Drainage - Data Worksheet

FDM 13-1-15 Culvert Material Selection Standard — *July 23, 2015*

15.1 Application

In general, WisDOT has approved steel, aluminum, concrete and plastic as suitable materials for culvert pipe. Coating systems for steel culvert pipe may be either zinc-coated (galvanized), aluminum or polymer. This procedure establishes criteria for selecting the proper combination of material and coating for different situations.

The standards in this procedure apply to all shapes of culvert pipe (circular, arch or elliptical) and to pipes in the range of 12 to 84 inches in diameter. The selection of larger drainage conduit is addressed in FDM13-1-20.

These standards are based on the expected service life of the material, the traffic volume to be supported and the location of the pipe (cross drain or side drain). Service life depends primarily on how durable the material is when subjected to corrosive or abrasive site conditions. Service life also depends on the proper structural design and installation of the pipe. These factors are considered in the Fill Height Tables of FDM13-1-25 as well as the standard specifications and the appropriate special provisions for individual projects.

15.2 Selection Standard

Reinforced concrete pipe is required for cross drains under major highways because it is a proven and dependable material that is not likely to need replacement because of corrosion or substandard installation. Replacement of culvert pipe under a major highway would not only be costly but also disruptive to the traveling public.

Standard Spec 520 - Pipe Culverts, categorize culvert pipe strengths by class, ranging from Class III with a maximum allowable fill height of 15 ft for reinforced concrete to Class V with a maximum fill height of 35 ft.

Within Class III there are four subclasses.

- Class III-A
    - includes Class II and III reinforced concrete, corrugated steel, corrugated polyethylene, and corrugated polypropylene.
    - Class III-A has a maximum fill height of 11 ft.
- Class III-B
    - includes reinforced concrete, corrugated steel and corrugated polypropylene
    - Class III-B has a maximum fill height of 15 ft.
- Classes III-A, Non-metal and Classes III–B, Non-metal
    - these classes are for corrosive environments where it is not advisable to use metal pipe.
    - therefore corrugated steel is removed from these non-metal subclasses.

The following list defines abbreviations commonly used throughout this chapter.

Material	Abbreviation
Corrugated Steel	CPCS
Corrugated Aluminum	CPCA
Corrugated Polyethylene	CPCPE
Corrugated Polypropylene	CPCPP
Reinforced Concrete	CPRC

The following table lists the materials permitted for culvert pipe by traffic volume range.

Table 15.1 Culvert Material Selection Criteria

MATERIAL	ABBR.	DESIGN ADT	ALLOWABLE SIZES (Inches)	NOTES
Reinforced Concrete	CPRC	Over 7000	12 - 84	Class III CPRC only in 42 - 84 inches
Corrugated Steel	CPCS	Under 7000	12 - 84	Not to be used in corrosive environments. See FDM 13-1-15.4
Corrugated Aluminum	CPCA	Under 1500	12 - 84	Refer to FDM 13-1 Attachment 25.6 for appropriate fill heights.
Corrugated Polyethylene	CPCPE	Under 7000	12 - 36	Max fill height of 11 ft.
Corrugated Polypropylene	CPCPP	Under 7000	12 - 36	Max fill height of 15 ft.

FDM 15-1-35 contains examples of the correct notations for specifying culvert pipe on a plan and profile sheet. FDM 15-1-30 shows how to indicate culvert types on the Miscellaneous Quantities Sheet.

For local road projects, the agency responsible for maintaining the culvert must approve the use of culvert pipe materials other than concrete.

15.3 Special Situations

Special conditions at the proposed culvert site may require that a specific type of pipe be used. Such special conditions include acidity of soils/water or other corrosive conditions, unusual loading from high embankments, steep gradients or other pertinent reasons.

15.4 Corrosion Concerns About Steel Culvert Pipe

Corrosion of zinc-coated (galvanized) steel pipe results from different mechanisms in different regions of the state. A Wisconsin map outlining the potential areas for bacterial corrosion of zinc galvanized steel culvert pipes is shown on Attachment 15.1. In the north and central part of Wisconsin (Area 1, Figure 15.1), corrosion of steel pipe is due mainly to the activity of anaerobic sulfate reducing bacteria (ASR) in the surface water. This region is characterized by low alkalinity of the surface water. These ASR bacteria do not attack the steel directly but create an environment favorable to corrosion. Corrosion resistant pipe should be specified for use in Area 1 with the exception of commonly dry sites where existing zinc-coated (galvanized) steel pipe have not had a history of corrosion.

In Area 2, zinc-coated (galvanized) steel pipe should be used only at sites where surface water has a minimum alkalinity of 120 milligrams per liter or where existing zinc-coated (galvanized) steel pipe at the site have had an acceptable service history. Metal culvert pipe of any type should provide a minimum service life of 20 years before perforation occurs.

In the remainder of the state (Area 3), corrosion is more commonly related to local conditions such as high electrical conductivity of water and fine grained soil. Other contributing factors would include high or low pH of soil or water and the presence of ASR bacteria in organic, poorly drained soil.

Corrosion resistant pipe may be necessary where drainage originates in bogs, swamps, barnyards or low-lying lands drained by ditches or tile. An acceptable corrosion resistant pipe should be specified in Area 3 when the pH is outside the range of five to nine and the resistivity is below 2000 ohm centimeters, or when the resistivity is below 1000 ohm centimeters regardless of the Ph. Acceptable corrosion resistant pipe materials are concrete, aluminum, aluminized steel, polymer coated steel, polyethylene and polypropylene.

* Note: Inspection of several aluminum drainage structures in 1993 revealed localized corrosion of the top and sides of the center sections of the structures. The corrosion appears to be related to the use of chlorides for snow and ice removal. The use of aluminum pipe should therefore be limited to side drains and highways with traffic volumes under 1500 Design AADT unless some provision is made to insulate the upper surface of the structure from infiltrating road salt.

Information about the corrosive characteristics of the soil or water at a site may already be available from region soils or maintenance records. In some cases it may be necessary to conduct field and laboratory tests to determine whether corrosive conditions exist. The region Soils Engineer can normally advise the designer about the need for such tests and conduct them if needed.

15.5 Abrasion Concerns

The thickness of metal pipe should be increased or the pipe invert paved where water velocity combined with a bed load of sand, gravel or stone is likely to cause significant erosion or abrasion of the pipe invert. The existence of abrasive conditions at a proposed culvert site can be determined from inspection of the existing metal pipe at the site or inspection of other pipes in the same general area or on the same watercourse.

15.6 Limited Clearance Installations

When a low clearance pipe is required, the designer may call for any of the following.

- Reinforced concrete elliptical or arch pipe
- Corrugated steel or aluminum pipe arch
- Structural plate pipe arch
- Aluminum structural plate pipe arch.

Arch pipe may also be warranted on the basis of special hydraulic design requirements.

15.7 Culvert Selection Justification

When special situations require the use of a non-standard type, shape or coating of pipe; relevant information to that determination should be included with the P.S. & E. submittal.

15.8 Tied Joints

Reinforced concrete pipe culverts are required to be tied at the joints with joint ties to prevent separation of adjacent pipe sections. This is required at the last 3 sections on the upstream and downstream ends of concrete culvert and concrete cattle pass installation. If using apron endwalls, tie the endwalls and the last 2 sections. No ties are required on culverts with masonry endwalls unless the plans show otherwise. Refer to standard spec 520 - pipe culverts. Include standard detail drawing "Joint Ties for Concrete Pipe" when using concrete culvert and concrete cattle pass pipe.

Pipe ties at all the joints in a pipe installation is very costly and should rarely be necessary. Where soil conditions or past experience with separation of RCCP sections at joints seem to justify an extensive use of pipe ties, a metal pipe may be a more cost effective pipe material.

Leakage of sand and silts from backfill material through the joints of concrete pipe can be a problem. If the leakage is significant, time and effort is required by the contractor to remove the material before the job can be accepted. Furthermore, unless the leakage stops, it could cause settlement of the backfill. Wrapping the joints with a band of geotextile fabric that laps onto each side of the joint by six to twelve inches is a method that can be used to prevent this problem.

LIST OF ATTACHMENTS

Attachment 15.1 Potential for Bacterial Corrosion of Zinc Galvanized Steel Culvert Pipe (Map)

FDM 13-1-17 Storm Sewer Material Selection Standard *July 23, 2015*

17.1 Purpose

This procedure provides guidelines for the selection of storm sewer materials.

Standard Spec 607 - Storm Sewer, categorize storm sewer pipe strengths by class, ranging from Class II with a maximum allowable fill height of 11 ft for reinforced concrete to Class V with a maximum fill height of 35 ft.

Within Class III there are two subclasses.

- Class III-A
  - includes Class II and Class III reinforced concrete, corrugated polyethylene, and corrugated polypropylene.
  - Class III-A has a maximum fill height of 11 ft.
- Class III-B
  - includes reinforced concrete and corrugated polypropylene
  - Class III-B has a maximum fill height of 15 ft.

17.2 Background

The following factors influence the selection of materials for storm sewers:

flow characteristics	life expectancy
physical strength	resistance to corrosion
ease of handling and installation	availability

Concrete pipe satisfies nearly all of these factors and therefore has been the traditional storm sewer pipe material specified by the department. Corrugated metal pipe has not been widely used because the corrugations decrease hydraulic capacity and, for corrugated steel pipe, the potential exists for the material to corrode and cause expensive maintenance or replacement of the pipe.

Corrugated polyethylene and corrugated polypropylene pipe with smooth interior walls, external ribs or corrugations, are materials that are now eligible for use on certain WisDOT projects within these guidelines.

Once it has been determined which storm sewer materials are suitable for a specific project or site, it is important to get the approval of any affected local government officials prior to developing final plans and specifications.

17.3 Approved Materials

The materials shown in Table 17.1 below may be used with the following restrictions.

TABLE 17.1 Materials in the Standard Specifications

MATERIALS	ABBR.	DESIGN ADT	ALLOWABLE SIZES (Inches)	NOTES
Reinforced Concrete	SSRC	All volumes	12 - 84	No restrictions
Composite	SSPC	All volumes	6 - 15	No restrictions
Corrugated Polyethylene	SSCPE	Under 7000	12 - 36	Max fill height of 11 ft.
Corrugated Polypropylene	SSCPP	Under 7000	12 - 36	Max fill height of 15 ft.

17.4 Criteria for Use of Corrugated Polyethylene and Corrugated Polypropylene Pipe

Reinforced concrete pipe may be used in all situations. Use of corrugated polyethylene and polypropylene is subject to the following limitations.

1. The agency responsible for maintaining the storm sewer approves the use of the alternate material.
2. The diameter of the pipe may not exceed 36 inches.
3. One or more of the following conditions exists:
   - Where design year traffic volume does not exceed 7000 ADT, all approved materials can be used regardless of whether or not the storm sewer will be located under a traffic lane.
   - Where the design year traffic volume exceeds 7000 AADT, corrugated polyethylene and

polypropylene may be specified for storm sewer located outside of traffic lanes such as the following locations:

- Behind curb and gutter.
- Under parking lanes where future use of the lane for through traffic is not expected.
- Under the median strips of divided roadways excluding paved areas such as turn lanes, cross streets, etc.
- Outside the limits of the roadway such as for outfall pipe.

Exception: Corrugated polyethylene, corrugated polypropylene, and composite pipe may be used for all storm sewer laterals 12 inches or less in diameter that must cross under traffic lanes to connect to longitudinal storm sewer pipe.

- At locations determined in cooperation with the Bureau of Technical Services for the purpose of gaining additional experience with the materials in a variety of traffic volume and site conditions.

17.5 Application and Specifications

The objective of specifying new materials is to take advantage of advances in materials technology. When new materials are approved for use as alternatives to traditional materials, the competitive bidding process is enhanced. Allowing contractors to bid on the basis of total installed cost for several materials should result in the lowest total cost for the storm sewer system. Therefore, it is desirable to allow all materials that meet engineering requirements for the project.

17.6 Tied Joints

In certain circumstances concrete pipe storm sewers are required to be tied at the joints with joint ties to prevent separation of adjacent pipe sections. This is required at the last 3 sections of the system infalls and outfalls. If using apron endwalls, tie the endwall and the last 2 sections. No ties are required on storm sewers with masonry endwalls unless the plans show otherwise (refer to standard spec 608 - Storm Sewers). Include standard detail drawings "Joint Ties of Concrete Pipes" when using concrete pipe storm sewers with infalls or outfalls.

Pipe ties at all the joints in a pipe installation is very costly and should rarely be necessary. Where soil conditions or past experience with separation of RCP sections at joints seems to justify an extensive use of pipe ties, the use of alternative pipe materials may be more cost effective.

Leakage of sand and silts from backfill material through the joints of concrete pipe can be a problem. If the leakage is significant, time and effort is required by the contractor to remove the material before the job can be accepted. Furthermore, unless the leakage stops, it could cause settlement of the backfill. Wrapping the joints with a band of geotextile fabric that laps onto each side of the joint by six to twelve inches is a method that can be used to prevent this problem.

17.7 Height of Cover

Height of cover for the pipe materials in Table 17.1 shall be in accordance with the values shown in FDM 13-1 Attachment 25.1. Minimum cover shall be 24-inches from top of pipe to top of subgrade. Height of cover for plastic pipe materials shall be as shown in Table 17.2.

TABLE 17.2 Fill Height Table for Corrugated Polyethylene and Polypropylene

		MAXIMUM COVER	
PIPE DIA.	MIN. COVER[1]	CORRUGATED POLYETHYLENE	CORRUGATED POLYPROPYLENE
12 in	2 ft	11 ft	15 ft
15 in	2 ft	11 ft	15 ft
18 in	2 ft	11 ft	15 ft
21 in	2 ft	11 ft	15 ft
24 in	2 ft	11 ft	15 ft
30 in	2 ft	11 ft	15 ft
36 in	2 ft	11 ft	15 ft

[1] Measured from top of pipe to top of subgrade where the pipe is under pavement. Minimum cover shall be 2 ft.

17.7 Roughness Coefficient

A constant coefficient of roughness value of 0.013 should be used in the Manning Formula for all of the storm sewer materials described in this procedure.

FDM 13-1-20 Large Drainage Conduit

December 18, 2015

20.1 Introduction

Large drainage conduit is defined in general as conduit larger than 84 inches in equivalent diameter, which equates in cross-sectional area to 38.5 square feet. This size was selected because it is near the top of the range of sizes at which pipe can be factory assembled while still being a practical size for transporting.

The types of large conduit available include structural plate pipe and structural plate pipe arch (AASHTO m167), aluminum alloy structural plate pipe and pipe arch (AASHTO m219), steel pipe with 3" x 1" corrugations (AASHTO m36), reinforced concrete pipe (AASHTO m170), reinforced concrete arch pipe (AASHTO m206), reinforced concrete elliptical pipe (AASHTO m207), and cast-in-place or precast box culverts (AASHTO m259).

The selection of a specific type of large conduit should be made on the basis of economics unless other considerations dictate the need for a particular type of large conduit. Other factors that should be considered include the availability of the conduit in the area of the project; foundation conditions at the project site; time available for construction, including consideration of how traffic will be handled; and the existence of corrosive or abrasive conditions at the site. Special hydraulic requirements, aquatic organism passage, or limited clearance conditions may require the use of a corrugated steel pipe arch, structural plate pipe arch, or wide box culvert.

Two or more conduit types may be specified as equal alternates when either type will satisfy design requirements. For example, aluminum structural plate pipe arch and (steel) structural plate pipe arch could be specified as equal alternates.

Multiple lines of pipe culverts or pipe arches may also be a feasible alternative to large drainage conduit.

FDM 13-1-21 Precast Box Culverts

December 18, 2015

21.1 Introduction

Precast box culverts are one of the large drainage conduit alternatives the designer may choose to resolve a given drainage problem. The choice of this option should be based on the criteria given in FDM 13-1-20 as well as sound engineering judgment. One factor that must be considered is earth cover. Fill height criteria for similarly sized cast-in-place culverts may be used, except precast box culverts may be used only in those situations which provide for at least two feet of earth cover under the traffic areas.

The broad range of sizes offers the designer many choices when studies indicate large drainage conduit is suitable. Multiple cell installations are permitted.

When determining whether a box culvert should be precast or cast-in-place, an analysis should be conducted to compare the options. This analysis should attempt to identify all the factors involved, including costs, many of which are not readily apparent.

Generally, initial cost of a cast in place box is less expensive than a precast box culvert. However, precast box culvert installation can be completed in a much shorter time than a cast-in-place option. This is especially of value where a detour is not feasible, and a short-term closure can be allowed. Precast box culverts may be used in emergency situations. In situations where complete closure is impossible, precast units can be used in a bypass, and then left in place or reset to a new position. Some local roads can carry detour traffic for short durations, but cannot sustain long-term use without costly maintenance and repair. Road user costs, such as delays due to indirection, may be a factor. Grading projects may realize a cost advantage by providing early access to an entire project, expediting movement of embankment materials and other construction operations. The minimum time and amount of disruption to streams is an easily identified positive environmental aspect.

Quality control of materials and curing conditions is an advantage to casting the units in a plant environment. The dry mix used in the units yields a denser, less permeable concrete than the cast-in-place option.

End treatments may be precast, cast-in-place, or a combination of both.

If a precast box culvert is selected for a particular design project, the designer shall notify the Bureau of Structures (BOS) early in scoping or design phase. If project is designed by a consultant, preliminary plans and complete final structure plans are required to be sent to BOS for approval. Please refer to 36.12 of the Bridge Manual (http://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/strct/bridge-manual.aspx).

FDM 13-1-25 Fill Height Tables — December 18, 2015

25.1 Design Criteria

The fill height tables included in this procedure are based on the following design criteria:

1. Weight of Embankment: 120 lbs/ft^3
2. Backfill: Good side fill material compacted to 90 percent of standard density based on AASHTO T 99. Modulus of passive soil resistance, E' = 1050 psi. Soil stiffness coefficient, K = 0.33.
3. Bedding: Class C, in accordance with the requirements of the Standard Specifications. The only exception to this bedding requirement is shown in Fill Height Table (Attachment 25.3), where a Class B bedding is required for reinforced concrete pipe placed under fill heights in excess of 35 ft (see Attachment 25.2). Load factors for the zero projecting embankment condition were used in the fill height determinations.

   For pipe arch structures, the confining backfill must be capable of supporting a corner pressure of two tons per square foot.
4. Safety factors: 4 for longitudinal seams; 2 for buckling.
5. Materials and fabrication: In accordance with the appropriate AASHTO specification as required by the Standard Specifications or special provisions.

25.2 Design Methods

The fill height tables for flexible conduit were developed using the service load design method described in the AASHTO LRFD Bridge Design Specifications. The fill height table for reinforced concrete pipe was developed using the design procedure included in the Concrete Pipe Design Manual prepared by the American Concrete Pipe Association.

25.3 Cut Ends

The ends of metal pipe cut as skews or mitered to slope (or both) are not as strong as square ends. Cut ends should be reinforced with concrete headwalls or collars when the bevel is flatter than 2:1 and the skew is greater than 20 degrees.

25.4 Multiple Structures

Where multiple lines of pipes or pipe arches greater than 48 inches in diameter or span are used, they shall be spaced so that the adjacent sides of the pipe are at least one-half diameter or three feet apart, whichever is less, to permit adequate compaction of backfill material. For diameters up to 48 inches the minimum spacing shall be 24 inches.

When multiple lines of pipe have less than half the diameter of the smallest pipe between them and the out-to-out length along the roadway reference line is greater than 20 feet, the pipe installation shall be assigned a B-number by the Region. Coordination with the Bureau of Structures is required in these situations.

25.5 Abrasive or Corrosive Conditions

Metal thicknesses shown in the fill height tables are adequate for structural requirements only. Where corrosive and/or abrasive conditions exist, either greater thicknesses or protective coatings should be provided. For structural plate pipe, greater thicknesses may be specified for the plates in the invert.

LIST OF ATTACHMENTS

Attachment 25.1	Storm Sewer Fill Height Table for Concrete Pipe
Attachment 25.2	Fill Height Table-Corrugated Steel, Aluminum, Polyethylene, Polypropylene and Reinforced Concrete Pipe, HS20 Loading, 2- 2/3in x 1/2in Corrugations
Attachment 25.3	Fill Height Tables: Corrugated Steel Pipe, 3in x 1in Corrugations; and Structural Plate Pipe, 6in x 2in Corrugations
Attachment 25.4	Fill Height Tables: Corrugated Steel Pipe Arch, 2- 2/3in x 1/2in Corrugations; and Corrugated Steel Pipe Arch, 3in x 1in Corrugations
Attachment 25.5	Fill Height Table, Structural Plate Pipe Arch, 6inx2in Corrugations
Attachment 25.6	Fill Height Tables: Corrugated Aluminum Pipe, 3in x 1in Corrugations; and Aluminum Alloy Structural Plate Pipe, 9in x 2 1/2in Corrugations
Attachment 25.7	Fill Height Table, Corrugated Aluminum Pipe Arch, 2 2/3in x 1/2in Corrugations
Attachment 25.8	Fill Height Table, Aluminum Alloy Structural Plate Pipe Arch, 9in x 2- 1/2in Corrugations
Attachment 25.9	Fill Height Table, Reinforced Concrete Arch and Elliptical Pipe (all sizes); and Dimensions for Reinforced Concrete Arch and Elliptical Pipe (English)